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The Sensorimotor Approach to Color Perception and the Necessity of Socio-cultural Considerations for Color Naming

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Introduction

It is generally believed that somewhere in the brain is an internal representation of the outside world that allows us to experience the world around us. The sense modalities take in information about the outside world, and our brains update our internal representation of the world in an attempt to keep us up to date about the world around us. One aspect of our account of the outside world that is of particularly intense debate is that of color ontology. An internal representation of the outside world, is supposedly, built up based on sensory data from our various sense modalities and therefore color would seem to be produced, through some neural mechanism, in our heads. On this view, sense information and its subsequent nervous influx cannot be defined in a way that closes certain explanatory gaps in color perception.

In opposition to the idea of neural mechanisms manufacturing color in the head is the sensorimotor approach to color vision, elaborated on by O'Regan and Noë in the paper *A sensorimotor account of vision and visual consciousness*. The idea of needing an internal representation of the world is rejected on this view, and it describes color as being an objective constituent of the world and our perception of color as being dependent on our interactions with the environment. Color, on this view, is a law that describes the way surfaces change the spectrum of the incoming light, and color experience is summarized by understanding the color of an object as the way its appearance varies given relevant circumstances, and vision is a type of exploratory activity in which we actively explore our world using our acquired mastery of so-called "sensorimotor contingencies" (O'Regan and Noë, 2001). That is to say, that according to sensorimotor theory we know a sheet of paper is red because of the way it appears to be red under the light, and we know this because we apprehend its red quality by exercising our implicit knowledge of the particular contingent sensorimotor laws that apply to visual apprehension. We look at the red sheet of paper, move it from bright light to shadow, view it

from different angles until we understand the color that best fits (O'Regan, 2010). As we become more skillful in our tacit understanding of the sensorimotor contingencies (sometimes also described as sensorimotor dependencies) the easier our apprehension of color becomes.

The Sensorimotor theory of color presented by O'Regan in his research subsequent to *A sensorimotor account of vision and visual consciousness*, argues that color exists objectively in the external world and his theory of how we process color (what he terms the "biological reflectance function") substantiates this claim through anthropological corroboration in the form of color naming tendencies among the various languages and cultures of the world. O'Regan's argument seems to hinge on the idea that certain color hues are more basic, or in his terminology "simpler," than other colors, and that given this simplicity these colors may be biologically more distinguishable than other colors, and therefore cultures may be more likely to attach a color name to that particular hue (Philipona and O'Regan, 2006). On this view, there is no explanatory gap standing between color experience and understanding the nature of color (O'Regan, 2010). According to the sensorimotor approach to consciousness the brain does not generate sensation, as sensations are not the kind of things that can be generated (O'Regan, "Why the Approach Is Not a Denial of the Brain"). Color is simply the way an illuminant changes the surface of an object, and color experience is our understanding of that surface change given our mastery of the sensorimotor contingencies involved in vision. Colors are understood as ontologically objective, and independent of the mind. As such, far from being unexplainable, on this view, our so-called qualia experience can be best explained as our skill with, and access to, sensorimotor contingencies.

In this paper I will argue against Kevin O'Regan's claim that the biologically restricted reflectance function (variously referred to in this paper as the "biological reflectance function") and its notion of "simple" colors naturally lead to a biologically consistent standard for species

wide color naming. Although the simplicity of these colors may allow for easier apprehension, the notion that color simplicity will naturally lead to a consistent standard for the naming of basic color hues across a species is inconsistent with the idea of objective colors in the way that he portrays it. While it fixes many of the traditional explanatory issues surrounding color perception, it opens up new explanatory issues surrounding color. In response to this I will argue that more emphasis must be put on the place of socio/cultural judgements and habits in the sensorimotor approach to color perception. In contrast to O'Regans assertion that culture follows natural tendencies to name certain colors, I argue that color naming follows socio-cultural considerations for color naming regardless of objectivity of color experience.

A comment on Enactivism and the Sensorimotor Approach

While both O'Regan and and Noë collaborated on what Kevin O'Regan refers to as his "magnum opus," namely the paper *A sensorimotor account of vision and visual consciousness*, since that time both have directed their work down different paths. Noë's focus since then has primarily been on strengthening the case for the "paradigm shift" towards enactivism (Kyselo, 2015). O'Regan's work on the other hand has primarily been focused on fleshing out the details of the sensorimotor approach. While enactivism and sensorimotor theory have, for many, become synonymous, it should be noted that there are differences. Enactivism considers consciousness an emergent phenomenon constituted of dynamic patterns of interaction between organism and its environment (Hutto, 2011). The sensorimotor approach is a theory of perceptual consciousness and is not a necessary constituent of an enactivist approach to consciousness, as in autopoietic enactivism (Scholarpedia, 2015). Only recently has O'Regan began describing the sensorimotor approach (sensorimotor enactivism) as a form of enactivism,

one that emphasizes perceptual abilities, as opposed to, say, autopoietic enactivism which stresses autopoietic capacities and background processes (Degenaar and O'Regan, 2015).

For the purposes of this paper I will refer to O'Regan's work on the sensorimotor theory alone, and where reference is made to *A sensorimotor account of vision and visual consciousness*, it is in the context of O'Regan's subsequent sensorimotor theory. That is to say that I am not emphasizing the greater enactivist paradigm, unless directly stated, but restrict my paper to that of O'Regan's sensorimotor theory of visual consciousness, specifically that of its color ontology.

A Biological Approach to Color

In the 2006 paper, *Color naming, unique hues, and hue cancellation predicted from singularities in reflection properties*, Philipona and O'Regan describe a reflectance function of a surface, what physicists use to define the reflectance of a surface, that has been "biologically" restricted by the nature of our visual apparatus (Philipona and O'Regan, 2006). For the purposes of this paper, I term this biologically restricted reflectance function as the *biological reflectance function*. The biological reflectance function describes surface reflectance in terms of how the wavelengths of light are processed by the three cone types the human visual apparatus possesses.

By analyzing this biological reflectance function, O'Regan argues that the color profile of any surface can be characterized by nine numbers which can be converted into a 3x3 matrix R and analyzed into a singularity index. In comparing this singularity index to anthropological studies of color naming across cultures a striking similarity is discovered. This similarity led O'Regan to postulate that color naming and color apprehension must be a biological consequence of the extreme singularity of certain color hues. The "simpler" and more singular

the color, as listed on O'Regan's singularity index, the more likely it is to acquire a name and become one of the "basic" colors of a culture's color system.

Sensorimotor approach to Color

The sensorimotor approach to color is best broken into two parts; the nature of color, and the experience of color through the exercise of sensorimotor contingencies. While the two parts are best explained separately, for reasons I will explain later, both the nature of color and the experience of it are sufficiently similar as to be functionally the same. The difference being that experience is restricted to the abilities of the human visual apparatus, and is dependent on our apprehension of color. The nature of the color of an object is a law that describes the way surfaces change the spectrum of the incoming light. That is to say, the ways in which the light (illuminant) changes the appearance of the object (reflectant). While the surface being viewed is changing the spectrum of the incoming light, it is the interaction between the incoming light and the surface that is contributing to the appearance of the surface. According to this view, a white piece of paper can appear green under green light, or yellow under yellow light. This interaction between the white sheet of paper and the varying color of illuminating lights is exactly what makes the paper a white sheet of paper, the fact that when under yellow light, the sheet of white paper now appears yellow.

Sensorimotor theory as it pertains to color experience, is summarized most simply by understanding the color of an object as the way its appearance varies given relevant circumstances. Colors are the ways in which objects are disposed to change their appearance as color-critical conditions change. For example, a plain white sheet of paper in a room lit with only red light would appear red, as the relevant conditions under which it is viewed are such that the only light being reflected from the paper are those of a red light. Under this view, the

plain white paper, is in fact, still white, but it appears to have become a red sheet of paper. On this view, color is not about lights, but about how surfaces reflect illuminating light. More specifically, color is the interaction between a surface, and the illuminating light. The color of the surface is intrinsic, but the surfaces color is reliant on the source of light for its appearance.

We experience an aspect of color given the particular circumstances in which we are viewing the object. Take the white sheet of paper out of a room saturated with red light, and into a room with a normal sunlit kitchen and the paper now appears white depending on where we are standing in relation to it. In order to investigate the color of the paper more thoroughly we must pick the paper up, move around it and view it from different angles, each new vantage gives us a better understanding of the character of the color of the paper.

The color of a surface is its tendency to change appearance in relation to the viewing conditions it is in. Viewing conditions are not restricted to changes in lighting sources, but are determined by the environment. Sticking with the white paper example, if the paper is placed on a dark marble kitchen countertop the paper will now appear to be a more bright white than it did before, because the nature of the white paper itself is changed by the darker surface in which it is currently surrounded. The ways in which colors change given color critical circumstances are defined by the nature of these circumstances. Given a particular light source, a particular environment, and a normal observer, the way in which a white sheet of paper will look can be determined objectively.

Color Character as Reflectance Function of a Surface

To explain what is meant by the way surfaces change the spectrum of the incoming light, and how we perceive the colors, consider one way in which physicists measure surface

color, or the reflectance function of a surface. The reflectance function of a surface expresses, as a function, what the reflected light from a surface will be, and allows it to be represented as a graph that indicates the surface reflectance of any given visible wavelength of light. In short, it details what proportion of the incident light energy of each wavelength is reflected off a given surface.

Unlike physicists, with spectrometers that precisely measure light energy at every wavelength, the human eye relies on photoreceptors that measure light using three cone types, those that measure the short, medium and long wavelengths. Because of the inherent limits of the human eyes apparatus for measuring light, the reflectance function of a surface used by physicists doesn't do much good for understanding our visual apprehension of color, which can not recognize light in individual wavelengths (O'Regan, 2010).

In the Sensorimotor approach, the nature of the color of an object is a law that describes the way surfaces change the spectrum of the incoming light and the experience of understanding the color of an object is the way its appearance varies given relevant circumstances. As such, human vision is understood as operating in the same practical way to determine color as the reflectance function of a surface does, but instead of using the exact precision of the spectrometer, human vision is restricted to the abilities of the three cone types. According to O'Regan, by restricting the function to those allowed for the human photoreceptors abilities (what Philipona and O'Regan call the "biological restriction"), and not those of a spectrometer, the reflectance of any surface can be given as nine numbers that define a 3x3 matrix R. In other words, these nine numbers will allow one to calculate, for any surface reflectance, the way in which the surface will affect the human visual apparatuses three cone types, or the human photoreceptor absorption function (Philipona and O'Regan, 2006).

The Biological Reflectance Function

What I have termed the "biological reflectance function," is composed of the so-called "LMS signal", and has two main components, that of the impinging spectrum, and cone fundamentals (Witzel, 2015). The human visual apparatus contains three types of photoreceptor cone cells, each with sensitivity to particular sections of the visual spectrum, those sensitive to what is deemed the long wavelengths, short wavelengths, and those wavelengths that fall in between (L,M,S). The excitation of the three types of cones (L,M,S), by incoming light hitting the retina, carries information about the color signal of the visual field. This color signal is referred to, by O'Regan, as the LMS signal (Witzel, 2015).

Light that actually hits the retina, from any source, is called the impinging light, and the spectrum of the light hitting the retina is called the *impinging spectrum*. In the case of the "biological reflectance function" light is viewed after having reflected off a surface, and therefore, there are two light spectrums that make up the impinging light, that of the light source, the illuminant, and the reflected surface, the reflectant. The impinging spectrum is the *linear combination* of the spectrum of the illuminating source (illuminant) and the spectral reflectance properties of the surface (reflectant) (Witzel, 2014).

The cone fundamentals on the other hand, are the sensitivities of the human photoreceptors. In the 2006 paper, *Color naming, unique hues, and hue cancellation predicted from singularities in reflection properties,* Philipona and O'Regan represented photoreceptor sensitivity by using the 10 degree Stiles and Burch color matching functions (Witzel, 2014).

In order to get the LMS signal that makes up the "biological reflectance function" the *cone fundamentals*, in this case the 10 degree Stiles and Burch color matching functions, must be applied to the *impinging spectrum* of the linear combination of the illuminant and the reflectant (Witzel, 2014).

Calculating the Color Singularity and 3X3 Matrix

According to Philipona and O'Regan (2006) calculating color singularity of surface reflectance can be broken down into two parts. The first concerns the impinging spectrum and the relationship of its two component parts, that of the illuminant spectrum, and the spectral reflectance property of the surface it is illuminating. As discussed earlier, the impinging spectrum is the wavelength composition of the impinging light (that light that hits the retina) and is made up of the *linear composition* of the illuminant spectrum (illuminant LMS), and the reflectance signals of the surface (reflectant LMS). This linear composition is used to calculate the impinging spectrum, and results in a map characterized as accurately linear by O'Regan and contributors (2015). Because of the linearity of the map of the impinging spectrums, Philipona and O'Regan found that by transforming the linear compositions of the impinging spectrum to a *3x3 transformation matrix A* a wide range of surface/illumination combinations could be approximated with nearly perfect accuracy (Witzel, Cinotti, O'Regan, 2015).

The second part of calculating color singularity deals with the behavior of the linear compositions of the impinging spectrums when transformed into the 3x3 matrix A. The impinging spectrum can be represented in a "cone-excitation space" a three dimensional space composed of the 3x3 matrix projections. For a typical impinging spectrum projected into the cone-excitation space the illuminant and reflectant variations will match up across the space, but in certain cases the matrix will project a two-dimensional, or one-dimensional subspace into the cone-excitation space and are called singular matrices. What this means is that certain impinging spectrums projected into the cone-excitation space have a more simple behavior than others, and thus, their color is more singular.

Singularity Index and the World Color Survey

As already covered, in order to determine the nine numbers that define the 3x3 matrix R, one must have the spectral reflectance property of a surface and its illuminants spectrum (the impinging spectrum), and the human photoreceptor absorption functions (cone fundamentals). Philipona and O'Regan tested their theory by calculating two sets of reflectances, one set composed of natural surfaces (leaves, flower petals, fruit etc.) and the other composed of artificial surfaces. For this, they chose a color stimulus palette composed of 1600 glossy surface Munsell chips as taken from the University of Joensuu (Parkkinen, 1989). For my purposes it is only necessary to discuss the artificial set of reflectances.

By applying the cone fundamentals of the *10-deg Stiles and Burch color matching function* to the impinging spectrum, and then to the Munsell Chip set, Philipona and O'Regan were able to create what they refer to as a singularity index, that is to say an index of how singular examples are of a given color, or hue (O'Regan, 2011). This singularity index based on the 1600 Munsell chips shows that the biologically restricted surface reflectance function points to six distinctly singular Munsell chips, those of the powerfully singular red and yellow chips, and those of the less singular blue, green, magenta and cyan chips (O'Regan, 2011 Supplemental/Unpublished Chapters). What distinguishes these six peaks of singularity is that the function has a more simple behavior than the rest of the functions of the graph (O'Regan 2010).

Interestingly, the Munsell chip stimulus palette used by Philipona and O'Regan to test their biologically restricted surface reflectance idea is the same stimulus palette used in the 1970's by two anthropologists from the University of California at Berkeley in what is now called the "World Color Survey." The World Color Survey sought to test the hypothesis that there existed universal constraints across languages in regards to color naming, and that there was a

partially fixed evolutionary progression of color language in which languages gain color terms over time (Kay, 2009). The survey collected the data of the color names of over 110 languages, by showing speakers of each language the Munsell chip stimulus palette and asking them to identify those colors that best represented each of the most basic colors of their language. The focal, or most basic, colors are represented on the munsell chip graph by four distinct peaks, with each peak listing the colored munsell chip that best represents the most basic colors. Most surprising perhaps is that each peak, constituted of each culture's choice for most basic color representation, are all uniformly chosen within one or two Munsell chips. For example the surprisingly singular basic color of “red” was almost unanimously represented by one munsell chip in particular, that of “G1.”

Both the World Color Survey and O’Regan and Philipona’s singularity index share a striking resemblance, with the latter's representation of the most singular colors falling within a couple Munsell chips of the World Color Survey. O’Regan suggests that the precision of the agreement of the simpler hues of the singularity index and the systematic way that “focal” colors were assigned names in the World Color Survey is an indication of a biological correspondence between the most simple colors (red, yellow) and our tendency to assign names to them. One reason O’Regan proposes that the more simple hues have a tendency to be given names is that perhaps their simple behavior in regards to illuminating light makes them more conspicuous than the other colors, and therefore more likely to be engaged across cultures (O’Regan, 2010).

Sensorimotor Theory and the Explanatory Gap

While the sensorimotor theory of color places color as existing objectively in the world, there is still an aspect of it that is experiential, namely the part that depends on the experience

of color. The experience of color is the perceived quality of the sensory experience, or as O'Regan defines it, the "feel". To most philosophers this "perceived quality" is more often referred to as the qualia of the experience, the ineffable "what it's like" quality. The sensorimotor theory, while accepting qualia, rejects the idea of qualia being ineffable. The sensorimotor theory does not support the idea that "feel" is generated in the brain, because feel is a way of interacting with the environment. Specifically, feeling is a skillful use of the sensorimotor contingencies to interact with the world.

According to sensorimotor color theory we all experience the same information coming into our visual apparatus, but given differences between human visual apparatuses our experience of that information will be different. But, in theory if we know the information coming in, in this case the spectral reflectance of the surface, and the exact biological limitations of the individual's visual apparatus (for example if they were colorblind, what wavelengths they could process and what wavelengths they could not) we can plot a singularity index for the individual akin to the one that O'Regan and Philipona plotted for the biological reflectance function.

Having a singularity index for the individual provides us with a possible way of understanding what the individual may be perceiving, it still doesn't explain the "feel" of experiencing a color such as red. According to O'Regan the experience of the "feel" of red has three possible parts, that of cognitive states, behavioral reactions, and physiological impulses. Cognitive states are those of mental association of the color red with previously experienced objects, knowledge of color relations, thoughts provoked by the redness of the object (e.g. linguistic associations) etc. Behavioral reactions are secondary aspects of the feel of an experience, and they include automatic reactions, such as pressing the gas at a green light. Physiological impulses are those physical states changed by the experience.

These elements of seeing the color red, O'Regan admits, are not exactly what is described when talking about the qualia of an experience. The above components of seeing red, are more appropriately described as components of what happens upon seeing red, and are more appropriately defined as being caused by the experience of seeing red. But, O'Regan argues, even if the actual experience of red appears ineffable, and therefore appears to lack ability to describe, within each modality we can compare and structure experiences, and make comparisons of comparisons and observe that some colors are more alike than others, and some colors are more different than others (O'Regan,"How to Build a Robot That Feels"). O'Regan argues that a way to make these comparisons and observations is to build something like the psychological colour solid which attempts to structure the "feel" or quality of color on a multidimensional scale (Clark, 1993 pg. 120–121). While psychological color solids like the one's described by Clark are part of accounts of a fully internalized and neurally "interpreted" psychological color solid, O'Regan is arguing to repurpose the actual color solids themselves as a means for computation of color experience existing only as an *external* method for categorizing color "feel."

Under traditional models of consciousness all of this would do little to alleviate the ineffability of qualia, but under sensorimotor theory, a careful analysis of all the constituent parts of the experience of the color red as outlined above, can describe "what it is like" for an individual to see the color red.

Problems of the biological reflectance function and qualia

As stated above, O'Regan argues that the singularity index, based on a biological reflectance function, and its correspondence to the world color survey is an indication of a biological approach to color naming. Namely, a process based on the biological singularity, or

asymmetry, of a color makes that color more simple to apprehend, and this simplicity leads, naturally, to our species naming them. In order for O'Regan's biological process of color naming to make sense though, it would seem to require some sort of logical process to color naming, meaning all colors sufficiently red-like, and not green-like, will be categorized as like colors. I argue that O'Regan's innate (as he terms it, biological) color discrimination approach to color naming is at odds with his argument that the "feel" of color is not generated in the brain. I argue this for two reasons; first if color naming followed natural biological processes, meaning color naming is based on a biological ability to color discriminate and is therefore innate, it would seem to imply that all color category systems would include like colors with like-colors.

In regards to color naming following a natural biological process, what I mean by this is that O'Regan argues that the "feel" of a color, and it's singularity are ultimately what contribute to that color being given a name, so therefore, the "feel" of red (determined through the careful analysis of the constituent parts of the "feel" of the color) is what leads red to be named its corresponding color name across language platforms.

But, if there are six main "singular" colors that humans apprehend most easily, and color naming tendencies are based on this ease of apprehension, this would seem to imply that the sufficiently simple enough color language would start off with at most six color terms (based on the examples in the singularity index), with each encompassing all sufficiently "like" colors. What this means is that the singularity of "red" would lead to all adequately "red" colors to be included under the "red" color term. I argue this because O'Regan argues that the "feel" of a color is not generated in the head, but derives from objective "feel" that exists in the world. If this were the case, then it should be clear to everyone with the same visual apparatus that dark red is closer to red, than it is to bright yellow.

If this were true though, and colors could be determined purely by "feel" it is not readily apparent why some cultures create color category systems that *do not* include like colors with like colors. For instance, the Himba people of Namibia have a color categorization system that is limited to five terms, and does not focus exclusively on like-colors.

The Himba color categorization system raises many questions for O'Regans innate "feel" based color discrimination theory. For instance, the term "Serandu" is relatively like-color based, within the color term is included some reds, purples and pinks. If we look at "Zoozu" though, it includes black, all dark shades of all colors, plus many none dark greens, blues, purples, and even some very light shades of purple and pink. Juxtaposing "Vapa" and "Borou" we see overlapping of like-colors also, with "Vapa" being white and many other light shades of various colors, and "Borou" being a range of yellows, greens, blues, purples, near browns, and almost pinks. If we look at the colors that overlap between them, we see many shades of blue, green and purple that are nearly identical in appearance, but are categorized differently. Interesting too, is that regardless of how different the colors within a color category appear to be to speakers of other languages, to the Himba a dark green and a light pink within a certain category are considered equally "focal" examples of that color. The overlap can be seen in all colors in the Himba system (Roberson, Debi, Jules Davidoff, Ian R.I. Davies, and Laura R. Shapiro, 2005). This overlap is puzzling from the perspective of O'Regan's "feel" based discrimination theory, as a light shade of pink, a dark shade of green, and a bright turquoise all share one color term. Even if one were to accept that there are basic universal color categories (red, yellow, green, blue, magenta, and cyan) and that the surrounding colors name tendencies were distorted by education, culture, or whatever, this would be problematic for the "feel" based nature of the discrimination system as even with this distorted color field, even though a bright pink and a bright blue are included under the same color term, it should be readily apparent how different these two colors appear.

This is not what is seen when color differentiation within color terms is studied. In fact, the opposite appears to be true. Colors that are categorized differently are apprehended by subjects as different colors, no matter how closely their hues resemble one another, and colors that are categorized under the same term are apprehended as appearing to be the same color. Subjects with different color category systems have been shown to be able to discriminate within their own color terms if the actual color difference is large enough, but the ability to differentiate is no better than an English speaker telling the difference between two close shades of green. That is to say, it may take a considerable amount of time for them to discriminate the color difference if at all. The most profound difference in discrimination is between different color terms that have colors that closely resemble each other.

For example, in Russian there is no generic color term for blue. Blue, as English speakers know it is split into two separate colors, siniy (dark blue) and goluboy (lighter blue) in the Russian color language. When tested against native English speakers in a variety of discrimination tests between siniy and goluboy it was found that native Russian speakers had an advantage in discrimination between the two colors, especially when the colors were very close hues to one another, but were categorized differently in Russian (Winawer, J., N. Witthoft, M. C. Frank, L. Wu, A. R. Wade, and L. Boroditsky, 2007).

Likewise, individuals of the Himba tribe were tested for color discrimination between and within color categories and it was found that the color categories themselves are what determined an individual's ability to discriminate colors, not a biological ability to discriminate. While obviously there is a biological ability to discriminate between colors, it made little difference in a subject's abilities to actually tell colors apart. Himba subjects were tested for color discrimination in two tests. One test used shades of color that were equally spaced in Munsell system perceptual metric (that is to say, a transition of color shades were shown, for

example, on one side basic green that slowly transitioned until it became blue at the other side), and subjects were asked to distinguish between the color categories. Within this test speakers of English would judge this to be a smooth transition between colors with no space between color shades. The Himba on the other hand viewed it to be an uneven spacing between Munsell cells, and clearly delineating between the various color categories of their language instead of viewing it as a transition between colors (Roberson, 2005; Goldstein, 2009). In another test two separate circular arrangements of color tiles were shown to test subjects. One arrangement contained shades that were all considered to be very close shades of green, close enough that most people could not tell them apart, but in the Himba color system one of these close shades of green belonged to another color category. The other arrangement contained one shade of easily discriminable blue, while the rest of the tiles were a shade of green, but in the Himba language all of these colors were part of one color category. For the Himba test subjects the first test containing all "like" colors was an easy task to pick the color tile that did not belong even though the color tiles all appeared to be the same color green to English speakers, while picking out the color that didn't belong in the second arrangement of color tiles proved much more difficult. In some cases even after long periods of time the Himba test subjects could not pick out the color that did not belong (Regier and Kay, 2009).

Color Categories and Color Discrimination

It is important to point out that O'Regan is making the claim that the abilities of our visual apparatus to discriminate colors is what leads to color categorization systems. I feel this is important to make clear, at this point, as O'Regan is not claiming his biological color naming system is one that is naturally based on an innate system of color categorization, as that would require a representational mental "prototype." O'Regan is claiming that we have a natural ability

to discriminate the six naturally “simple,” or singular, colors of red, yellow, green, blue, magenta, and cyan, exactly because of their singularity. This means that we have a natural ability to pick out “basic” red as being a distinct color easier than any other color, and because we can easily pick it out, we have a natural tendency to assign it a name. In this way, O’Regan implies that color naming is an issue of memory, as colors are there in the world. Our biological systems merely give us the ability to discriminate some colors easier than others, as these colors have sensorimotor contingencies that are easier to grasp than others.

But it is arguable if an account of the discriminations made by the visual system can account for the structural relations between different color experiences. As such I argue that if color categorization systems do come about because of a natural ability to color discriminate those six color terms, then all sufficiently like colors should be categorized with their like colors as in the sensorimotor approach to color there is no mental representation of color, and no color qualia. If it is not the case that all like colors are categorized under that same colors then there is no accounting for exactly what color viewers are seeing, or why they are unable to discriminate colors that are so distinct to other viewers. The visual system of the Himba and an English speaker are the same, and as such, we have the abilities to see the same colors and therefore we should be able to discriminate between the same colors. Thus, if O’Regan’s sensorimotor approach to color perception and color naming is correct it demands a universal color language, but as outlined earlier, this is not the case.

Analysis

O’Regan’s sensorimotor approach to color makes clear that apprehension of different colors is a matter of mastery of pertinent sensorimotor contingencies, and memory. As such, the first colors to be understood would be those that have the most simple sensorimotor laws

to master. According to the work of Philipona and O'Regan (2006) the colors with the most simple sensorimotor contingencies are those that are considered the most singular on the singularity index (red, yellow, green, blue, magenta, and cyan) and that all other colors would be described as one of those six categories until their sensorimotor laws are understood. For instance, a color such as brick red, would appear to be just red, or perhaps "reddish" until their sensorimotor laws are understood, but once they are understood they would be clearly apprehended as a distinct color, that of brick red. In this way, colors are understood based on their relation, or likeness, to the original "singular" colors. I contend that this is exactly where the sensorimotor approach runs into a problem. If colors were apprehended in a gradual acquisition of new colors as the sensorimotor approach implies, there should one be a universal color language across all cultures, but as has already been shown, this is not the case.

I agree with the 2006 Philipona and O'Regan paper *Color Naming, Unique Hues, and Hue Cancellation Predicted from Singularities in Reflection Properties* when it shows that some colors are easier to apprehend than others based on their singularity corresponding to more simple sensorimotor contingencies, but I believe this *ease of apprehension* is not an indication of how color categories are formed, and is perhaps merely coincidental to the way that colors have been named and categorized.

Conclusion

In this paper I have attempted to refute Kevin O'Regan's claim that the "biological reflectance function" and its notion of "simple" colors naturally lead to a biologically consistent standard for species wide color naming. Although the simplicity of these colors may allow for easier apprehension, the notion that color simplicity will naturally lead to a consistent standard

for the naming of basic color hues across a species is inconsistent with the idea of objective colors in the way that he portrays it. While it fixes many of the traditional explanatory issues surrounding color perception, it opens up new explanatory issues surrounding color. In response, I argue that more emphasis must be put on the place of socio/cultural judgements and habits in the sensorimotor approach to color perception. In contrast to O'Regans assertion that culture follows natural tendencies to name certain colors, I argue that color naming follows socio-cultural considerations for color naming regardless of objectivity of color experience.

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